APPENDIX E

ELECTRICAL ENGINEERING DESIGN CRITERIA

E.1 INTRODUCTION

Project design, engineering, procurement, and construction activities will be controlled in accordance with various predetermined standard practices and project-specific programs/practices. An orderly sequence of events for project implementation is planned, consisting of the following major activities:

- Conceptual design
- Licensing and permitting
- Detailed design
- Procurement
- Construction and construction management
- Checkout, testing, and startup
- Project completion

This appendix summarizes the codes and standards, standard design criteria, and industrial good practices that will be used during the project. The general electrical design criteria defined herein form the basis of the design for project electrical components and systems. More-specific design information will be developed during detailed design to support equipment and erection specifications. It is not the intent of this appendix to present the detailed design information for each component and system, but rather to summarize the codes, standards, and general criteria that will be used.

Section E.2 summarizes the applicable codes and standards, and Section E.3 includes the general design criteria for motors, power and control wiring, protective relaying, classification of hazardous areas, grounding, lighting, heat tracing, lightning protection, raceway and conduit, and cathodic protection.

E.2 DESIGN CODES AND STANDARDS

Work will be designed and specified in accordance with applicable laws and regulations of the Federal Government and the State of California and applicable local codes and ordinances.

The following general codes and industry standards will be used in design and construction:

- Antifriction Bearing Manufacturers Association (AFBMA)

- American National Standards Institute (ANSI)
- American Society for Testing and Materials (ASTM)
- Insulated Cable Engineers Association (ICEA)
- Institute of Electrical and Electronics Engineers (IEEE)
- Illuminating Engineering Society (IES)
- National Electrical Code (NEC)
- National Electrical Manufacturers Association (NEMA)
- National Electrical Safety Code (NESC)
- National Fire Protection Association (NFPA)
- Occupational Safety and Health Act (OSHA)
- Underwriters' Laboratories Inc. (UL)

In addition to these general codes and standards, the following specific standards will be used:

- Batteries

IEEE 450	Recommended Practice for Maintenance, Testing, and Replacement of Large Lead Storage Batteries
IEEE 484	Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations

- Battery Chargers

NEMA AB-1	Molded Case Circuit Breakers
NEMA PE-5	Electric Utility Type Battery Chargers

- Cable: Low Voltage Power, Control, and Instrument

ASTM B 3	Standard Specification for Soft or Annealed Copper Wire
ASTM B 8	Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

ASTM B 33	Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes
ASTM B 496	Standard Specification for Compact Round Concentric-Lay-Stranded Copper Conductors
ICEA S-66-524 (NEMA WC 7)	Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
ICEA S-68-516 (NEMA WC 8)	Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
ICEA S-73-532 (NEMA WC 57)	Standard for Control Cables
ICEA S-82-552 (NEMA WC 55)	Instrumentation Cables and Thermocouple Wire
IEEE-1202	Standard for Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies
NEC	National Electrical Code, NFPA 70
NEMA WC 26	Wire and Cable Packaging

- Cable: Medium Voltage Power

ASTM B 3	Standard Specification for Soft or Annealed Copper Wire
ASTM B 8	Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
ASTM B 33	Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes
ASTM B 496	Standard Specification for Compact Round Concentric-Lay-Stranded Copper Conductors
ICEA S-66-524 (NEMA WC 7)	Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical

	Energy
ICEA S-68-516 (NEMA WC 8)	Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
IEEE-1202	Standard for Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies
NEC	National Electrical Code, NFPA 70
NEMA WC 26	Wire and Cable Packaging
UL 1072	Standard for Medium-Voltage Power Cables

- Cable Tray

NEMA VE-1	Cable Tray Systems

- Cathodic Protection Equipment

ANSI B1.1	Unified Inch Screw Threads
ANSI B2.1	Pipe Threads
ASTM A 518	Corrosion-Resistant High Silicon Cast Iron
ASTM B 418	Cast and Wrought Galvanic Zinc Anodes for Use in Saline Electrolytes

- Circuit Breakers, High Voltage

ANSI/IEEE C37.04	Rating Structure for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
ANSI C37.06	Preferred Ratings and Related Required Capabilities for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
ANSI/IEEE C37.09	Test Procedure for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis

ANSI/IEEE C37.010	Application Guide for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
ANSI C37.11	Requirements for Electrical Control for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis and a Total Current Basis

- Conduit

UL 6, ANSI C80.1	Rigid Steel Conduit
UL 797, ANSI C80.3	Electrical Metallic Tubing
UL 514, ANSI C80.4	All Fittings
UL 886	Hazardous Area Fittings
UL 360	Flexible Liquid-tight Conduit
NEMA TC6	PVC and ABS Plastic Utilities Duct for Underground Installation
NEMA TC9	Fittings for ABS and PVC Plastic Utilities Duct for Underground Installation
UL 651	Electrical Rigid Nonmetallic Conduit
NEMA TC2, UL 514	Fittings for Electrical Rigid Nonmetallic Conduit

- Distribution Panels

ANSI C97.1	Low Voltage Cartridge Fuses, 600 volts or less
NEMA AB-1	Molded Case Circuit Breakers
NEMA PB-1	Panelboards
UL 50	Electrical Cabinets and Boxes

UL 67	Panelboards
NEMA ICS	Industrial Controls and Systems
NEMA KSI	Enclosed Switches

- Grounding Cable

ASTM B8	Specifications for Concentric-Lay Stranded Copper Conductors

- Grounding Connectors and Accessories

NEMA CC-I	Electrical Power Connectors for Substations

- Lighting Fixtures

NEMA FA-1	Outdoor Floodlighting Equipment
NEMA LE-1	Fluorescent Luminaries
UL 57	Standard for Safety, Electric Lighting Fixtures
UL 844	Standard for Safety, Electric Lighting Fixtures for Use in Hazardous Locations
UL 924	Standard for Safety, Emergency Lighting Equipment

- Lightning Arresters

ANSI/IEEE C62.11	Standard for Metal-Oxide Surge Arresters for AC Power Circuits

- Secondary Unit Substations

ANSI C37.13	Low-Voltage AC Power Circuit Breakers Used in Enclosures

ANSI C37.16	Preferred Ratings, Related Requirements, and Application Recommendations for Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors
ANSI/IEEE C37.20.1	Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear
ANSI/IEEE C37.20.2	Standard for Metal-Clad and Station-Type Cubicle Switchgear
ANSI C37.50	Test Procedures for Low-Voltage AC Power Circuit Breakers Used in Enclosures
ANSI C37.51	Conformance Testing of Metal-Enclosed Low-Voltage AC Power Circuit Breaker Switchgear Assemblies
ANSI C57.12.00	General Requirements for Distribution, Power, and Regulation Transformers
ANSI/IEEE C57.12.01	General Requirements for Dry-Type Distribution and Power Transformer
ANSI/IEEE C57.12.90	Test Code for Liquid Immersed Distribution, Power, and Regulating Transformers
ANSI/IEEE C57.12.91	Test Code for Dry-Type Distribution and Power Transformers

- Metal-Clad Switchgear and Nonsegregated Phase Bus

ANSI A58.1	Minimum Design Load in Buildings and Other Structures
ANSI C37.04	Rating Structure for AC High-Voltage Circuit Breakers on a Symmetrical Current Basis
ANSI C37.06	Preferred Ratings and Related Required Capabilities for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
ANSI C37.20	Switchgear Assemblies Including Metal-Enclosed Bus
ANSI C37.23	Guide for Metal-Enclosured Bus and Calculating Losses in Isolated-Phase Bus

ANSI C57.13	Requirements for Instrument Transformers

- Motor Control Centers

NEMA ST-20	Dry-Type Transformers for NEMA General Purpose Applications
NEMA AB-1	Molded Case Circuit Breakers
NEMA ICS-1	General Standards for Industrial Controls and Systems
NEMA ICS-2	Industrial Control Devices, Controllers, and Assemblies
UL 489	Molded Case Circuit Breakers and Circuit Breaker Enclosures
UL 508	Industrial Control Equipment
UL 845	Motor Control Centers

- Motors, Low Voltage

NEMA MG-1	Motors and Generators
AFBMA 9/ANSI B3.15	Antifriction Bearing Manufacturers Association
NEMA MG-2 APBMA 11/ ANSI B3.16	Safety Standard for Construction and Guide for Selection, Installation, and Use of Electrical Motors and Generators
NEMA MG-13	Frame Assignment for Alternating Current Integral Horsepower Induction Motors

- Motors, Medium Voltage

ANSI/IEEE C50.41	Polyphase Induction Motors for Electric Power Generating Stations
IEEE 112	Test Procedure for Polyphase Induction Motors and Generators

NEMA MG-1	Motors and Generators
NEMA MG-2	Safety Standard for Construction and Guide for Selection, Installation, and Use of Electrical Motors and Generators

- Neutral Grounding Resistors

ANSI C76.1	Requirements and Test Costs for Outdoor Apparatus Bushings
IEEE 32	Requirements, Terminology, and Test Procedures for Neutral Grounding Devices

- Relay Panels

ANSI C37.20	Switchgear Assemblies Including Metal-Enclosed Bus
ANSI C37.90	Relays and Relay Systems Associated with Electric Power Apparatus

- Transformers, Dry-Type

ANSI U1	General Requirements for Dry-Type Distribution and Power Transformers
NEMA ST-20	Dry-Type Transformers for General Application
UL 506	Standard for Safety, Specialty Transformers

Other recognized standards will be used as required to serve as design, fabrication, and construction guidelines when not in conflict with the above-listed standards.

The codes and industry standards used for design, fabrication, and construction will be the codes and industry standards, including all addenda, in effect as stated in equipment and construction purchase or contract documents.

E.3 ELECTRICAL DESIGN CRITERIA

E.3.1 Electric Motors

E.3.1.1 General Motor Design Criteria

These paragraphs outline basic motor design guide parameters for selecting and purchasing electric motors. The following design parameters will be considered:

- Motor manufacturer
- Environment, including special enclosure requirements
- Voltage, frequency, and phases
- Running and starting requirements and limitations and duty cycle
- Motor type (synchronous, induction, dc, etc.) and construction
- Power factor
- Service factor
- Speed and direction of rotation
- Insulation
- Bearing construction, rating life of rolling elements, and external lube oil system for sleeve or plate bearings
- Ambient noise level and noise level for motor and driven equipment
- Termination provisions for power, grounding, and accessories
- Installation, testing, and maintenance requirements
- Special features (shaft grounding, temperature and vibration monitoring, surge protection, etc.)
- Motor space heater requirements

E.3.1.1.1 Safety Considerations for Motors. The Occupational Safety and Health Administration rules will be followed for personnel protection. Belt guards will be specified for personnel safety and, when required, to prevent foreign objects from contacting belt surfaces. Guard screens will be provided over motor enclosure openings to prevent direct access to rotating parts. Electrical motors will be adequately grounded.

Motors in hazardous areas will conform to applicable regulatory requirements and will be UL labeled. Motor electrical connections will be terminated within oversized conduit boxes mounted to the motor frame.

E.3.1.1.2 Codes and Standards. Motors will be designed, manufactured, and tested in accordance with the latest applicable standards, codes, and technical definitions of ANSI, IEEE, NEMA, and AFBMA, as supplemented by requirements of the specifications.

E.3.1.1.3 Testing Requirements. Each type of ac and dc machine will be tested in accordance with the manufacturer's routine tests at the factory to determine that it is free from electrical or mechanical defects and to provide assurance that it meets specified requirements. The following criteria and tests will be used in testing each type of machine:

- Fractional horsepower, single-phase induction motors (< 3/4 hp)

  Test procedures will be in accordance with IEEE 114, Test Procedure for Single Phase Induction Motors.

- Integral horsepower, three-phase, 460 V induction motors (3/4 - 250 hp)

  Use routine tests listed in NEMA MG1-12.51, Routine Tests for Polyphase Integral Horsepower Induction Motors.

  Test procedures will be in accordance with IEEE 112, Test Procedure for Polyphase Induction Motors and Generators.

- Induction motors rated above 600 V (≥ 251 hp)

  Routine tests listed in NEMA MG1-20.46, Polyphase Induction Motors for Power Generating Stations, will be performed on each motor.

The following additional tests and inspections will be performed on each motor larger than 1,500 hp. However, when duplicate motors are provided, perform the tests on one motor only.

- Locked-rotor current at fractional rated voltage
- Current balance
- Length of time of bearing test and final temperature rise of bearing
- A statement that bearings have been inspection and approved for shipment
- Insulation resistance-time curve and polarization index for motors with formed-coil stators
- Final value of motor noise levels, including statement that there is no objectionable single frequency noise
- Final air gap measurements (single air gap)

Motors that are specified to have complete tests performed on either the furnished motor or an electrically duplicate motor will require the following tests:

- Temperature
- Percent slip
- No-load saturation curve
- Locked-rotor saturation curve, including locked-rotor torque, current, and power
- Speed-torque and speed-current curves at rated voltage and at minimum starting voltage
- Efficiency at full, three-fourths, and one-half loads
- Power factor at full, three-fourths, and one-half loads

- Direct current motors

  The following standard routine tests and inspections will be performed on each motor:

  – High potential dielectric test

  – Measurement of resistance of all windings

  – Inspection of bearings and bearing lubrication system

  – No-load running armature current, shunt field current, and speed in revolutions per minute, at rated voltage

  – Full-load armature current, shut field current, and speed in revolutions per minute, at rated voltage

  Test procedures will be in accordance with IEEE 113, Test Code for Direct Current Machines.

E.3.1.1.4 <u>Electrical Design Criteria</u>. Special requirements for individual motors and specifications for special application motors will be included in individual specification technical sections. The motor nameplate horsepower multiplied by the motor nameplate service factor will be at least 15 percent greater than the driven equipment operating maximum brake horsepower. For motors with 1.15 service factor, the maximum load brake horsepower will not exceed the motor nameplate horsepower.

Emergency dc motors will operate continuously at the nominal system voltage with any supply voltage between 84 and 112 percent of the nominal 125 VDC system voltage.

Alternating current motors will be designed for full-voltage starting and frequent starting, where required, and will be suitable for continuous duty in the specified ambient conditions. Intermittent-duty motors will be selected where recognized and defined as standard by the equipment standards and codes.

The torque characteristics of induction motors will be as required to accelerate the inertia loads of the motor and driven equipment to full speed without damage to the motor or the equipment at any voltage from 90 to 110 percent of motor nameplate voltage, except those to be individually specified.

Temperature Considerations. Integral horsepower motors will be designed for an ambient temperature of 40° C.

Windings and Insulation. Insulated windings will have Class F nonhygroscopic insulation systems with Class B temperature rise and ambient temperature in accordance with NEMA MG1 standards.

Insulated stator winding conductors and wound-rotor motor secondary windings will be copper. The insulation resistance corrected to 40° C will be not less than motor rated kV +1 megohms for all windings. Where required, the windings will be treated with a resilient, abrasion-resistant material.

Overspeeds. Squirrel-cage and wound-rotor induction motors, except crane motors, will be so constructed that in an emergency of short duration they will withstand, without mechanical injury, overspeeds above synchronous speed in accordance with the table in NEMA MG1-12.48, Overspeeds for Motors.

Space Heaters. Space heaters will be sized as required to maintain the motor internal temperature above the dew point when the motor is not running. Motor space heaters will not cause winding temperatures to exceed rated limiting values or cause thermal protective device over-temperature indication when the motor is not energized.

In general, motors 1,000 hp or larger will have 240 V, single-phase, 60 Hz rated space heaters and will be energized by a 120 V, single-phase, 60 Hz system. All 4,000 V motors will have space heaters. Heaters will be located and insulated so that they do not damage motor components or finish. Space heater leads will be stranded copper cable with 600 V insulation and will include terminal connectors.

Nameplates. Motor nameplate data will conform to NEMA MG1-20.60 requirements. The following additional nameplate data will be included for 4,000 V rated motors:

- Manufacturer's identification number
- Frame size number
- Insulation system class designation

- Maximum ambient temperature for which the motor is designed or the temperature rise by resistance
- Service factor
- Starting limitations
- Direction of rotation and voltage sequence
- AFBMA bearing identification number for motors furnished with rolling element bearings
- For motors with connections to an external lubricant recirculating system or with an integral forced lubrication system, oil pressure and oil flow required
- For motors designed for service in hazardous areas:
  - Location class and group designation
  - Maximum operating temperature value or operating temperature code number

Environment. Location of individual motors within the plant will determine ambient temperature, corrosive environment, hazardous environment, and humidity to be experienced by the motors. These conditions will be considered in the purchase specification.

E.3.1.2 4,000 Volt Squirrel-Cage Induction Motors

E.3.1.2.1 Design and Construction. Design and construction of 4,000 V motors will be coordinated with the driven equipment requirements.

Motor power lead terminal housings will be adequately sized to terminate the power conductors. For 4,000 V motors, the power lead terminal housing will also be large enough to provide working space for field fabrication of stress cones within the housing and to contain the stress cones after installation.

Separate terminal housings will be provided for:

- Motor power leads

- Motor accessory leads
- Motor temperature detector leads

Leads will be wired into their respective terminal housings. Motor leads and their terminals will be permanently marked in accordance with the requirements of NEMA MG1, Part 2. Each lead marking will be visible after the terminals are taped.

Motors designed to rotate in only one direction will have the direction of rotation marked by an arrow mounted visibly on the stator frame near the terminal housings or on the nameplate and the leads marked for phase sequence T1, T2, T3 to correspond to the direction of rotation and supply voltage sequence.

Outdoor motors will be TEFC with NEMA waterproof features or NEMA WPII. Indoor motors in wet areas will have outdoor motor features.

Exposed metal surfaces of motors for outdoor service will be protected with a corrosion-resistant coating.

E.3.1.2.2 <u>Insulation</u>. All motors shall be furnished with Class F or Class H insulation systems, provided the temperature rise is based on Class B maximum. An insulation resistance time curve corrected to 40°C for determining the polarization index for motor stator windings will be taken immediately before making the final high potential ground test. Each stator phase will be tested separately to ground, with other phases grounded. Motors will be tested at not less than 5,000 VDC. The ambient temperature, winding temperature, and relative humidity values will be included with the recorded data. The polarization index will not be less than 3.0. An insulation-to-ground dielectric test will be made on the motor windings at a value of two times rated voltage + 1,000.

E.3.1.2.3 <u>Bearings</u>. Horizontal motors, except motors for belted drives, will have split sleeve bearings of oil ring type, unless required otherwise.

Sleeve bearings on horizontal motors will be designed and located centrally with respect to running magnetic center to prevent the rotor axial thrust from being continuously applied against either end of the bearing. The motors will be able to withstand without damage the axial thrusts developed when the motor is energized.

When sleeve bearings are not specified, horizontal motors will have antifriction bearings.

Thrust bearings for vertical motors will be able to operate for extended periods of time at any of the thrust loadings imposed by the specific piece of driven equipment during starting and normal operation, without damage to the bearings, the motor frame, or other motor parts.

Motors with spherical roller thrust bearings will also have ball or roller guide bearings. Bearing lubricants will contain a corrosion inhibitor. The type and grade of lubricant will be indicated on a nameplate attachment to the motor frame or end shield adjacent to the lubricant filling device. Insulation will be provided on bearing temperature detectors and on oil piping connections when required to prevent circulation of shaft current through bearings. Bearings and bearing housings will be designed to permit disassembly in the field for bearing inspection or rotor removal.

E.3.1.2.4 <u>Bearing Temperature Detectors</u>. Thermocouple bearing temperature detectors, complete with detector head and holder assemblies as required, will be furnished. Thermocouple lead wire insulation will be color-coded with standard colors to represent the thermocouple metals.

E.3.1.2.5 <u>Winding Temperature Detectors</u>. Winding temperature detectors will be furnished, installed, and wired complete. Temperature detectors will normally be three-wire resistance platinum temperature detectors (RTDs).

E.3.1.2.6 <u>Temperature Detector and Terminal Block Requirements</u>. Temperature detectors will be ungrounded, with detector leads wired to terminal blocks furnished in the accessory terminal housings. A grounding terminal for each temperature detector will be included with the detector lead terminals. The grounding terminals will be wired internally to a common ground connection in each terminal box. The internal wiring will be removable.

E.3.1.3 <u>460 Volt Integral Horsepower Motors</u>

E.3.1.3.1 <u>Design and Construction</u>. Design and construction of each 460 V integral hp motor will be coordinated with the driven equipment requirements and the requirements of NEMA MG1 standards.

Motors for service in hazardous areas will be individually considered as to type of enclosure, depending on the classification, group, and division of the hazardous area in question.

Exposed metal surfaces of motors for outdoor service will be protected with a corrosion-resistant coating.

Motor power lead terminal housing will be sized to allow for ease in terminating the incoming power cable. Space heater leads will also be routed into this terminal housing.

E.3.1.3.2 Bearings. Horizontal motors will have oil or grease-lubricated sleeve or antifriction bearings, unless otherwise required.

Bearings on horizontal motors will be designed and located centrally with respect to the running magnetic center, to prevent the rotor axial thrust from being continuously applied against either end of the bearings. The motors will be able to withstand without damage the axial thrusts developed when the motor is energized.

Vertical motors with spherical roller thrust bearings will also have ball or roller guide bearings. Thrust bearings for vertical motors will be able to operate for extended periods of time at any of the thrust loadings imposed by the specific piece of driven equipment during starting and normal operation without damage to the bearing, the motor frame, or other motor parts.

Bearings and bearing housings will be designed to permit disassembly in the field for bearing inspection or rotor removal.

E.3.1.4 Direct Current Machines

E.3.1.4.1 Design and Construction. Direct current machines will be designed and constructed for continuous operation and in accordance with NEMA MG1. Direct current motors rated at 120 V will be capable of accelerating their loads and operating continuously through a voltage range of 105 to 140 VDC.

E.3.1.4.2 Service Factor. For motors furnished with a service factor greater than 1.0, the motor nameplate will indicate the horsepower rating at 1.0 service factor and the service factor. The motor will be designed to provide a continuous horsepower capacity equal to the rated horsepower at 1.0 service factor without exceeding the total limiting temperature rise stated in these specifications for the insulation system and enclosure specified.

E.3.1.4.3 Insulation and Windings. Insulated windings will have a minimum of Class B nonhygroscopic, or acceptable equivalent, sealed insulation system. Insulated winding conductors will be copper.

E.3.1.4.4 Armatures and Brushes. Commutator bars will be fabricated of silver-bearing copper and will be free of cracks, pits, slivers, and similar imperfections. Bars will be insulated with mica segments, assembled and seasoned as a unit, properly undercut, and securely mounted on the shaft. The area behind the armature commutator risers will be packed with an epoxy compound and cured. Coil end connections to the risers will be either soldered with high temperature, pure tin solder; brazed; or tungsten inert-gas welded.

Brush holders will be fabricated of nonferrous materials, located accurately, and mounted securely to position the brushes on the armature. Brush holder pockets will be sized to permit proper movement of the brushes. Means for adjusting brush pressures and brush assembly ring will be provided. A stop device will be furnished to prevent the brush terminal from scoring the commutator.

Brushes will be carbon, with insulated shunts sized for the rated brush current. Successful commutation in accordance with NEMA standards will be maintained over the load range encountered in service.

Openings will be provided for ease of inspection, pressure adjustment, and replacement of brushes, and for brush assembly ring adjustment.

E.3.1.4.5 Bearings. Sleeve bearings for horizontal motors will be oil-ring lubricated unless otherwise required. The oil ring will be one-piece construction.

E.3.1.5 Fractional Horsepower Motors

The type, design, and construction of each general, special, and definite purpose fractional horsepower motor will be coordinated with the driven equipment requirements and will be in accordance with the requirements of NEMA MG1. Motors for service in hazardous areas will be individually considered for type of enclosure, depending on the classification, group, and division of the hazardous area in question.

Motors will be totally enclosed unless specified otherwise.

Exposed metal surfaces of motors for outdoor service will be protected, where practical, with a corrosion-resistant coating. Enclosure exterior and interior surfaces, air gap surfaces, and windings will be protected with a corrosion-resistant epoxy paint or coating.

Bearings will be self-lubricating and will be designed to operate in any position or at any angle.

E.3.1.6 Motor Operators for Nonmodulating Valve, Gate, or Damper Service

The following requirements are applicable to electric operators required for nonmodulating motor operators.

E.3.1.6.1 Rating, Design, and Construction. Motors will be designed for high torque, reversing service in a 40° C ambient temperature. Motors will have Class B or higher nonhygroscopic standard insulation plus two coats of epoxy resin. Requirements of NEMA MG1 and MG2 will apply.

Motors will be rated 460 V, three-phase, 60 Hz, unless otherwise indicated. The dc motors will be rated 120 VDC to operate from a nominal 125 V battery.

The motor time duty rating for normal opening and closing service will be not less than whichever of the following is greater:

- As required for three successive open-close operations
- As required for the service
- Not less than 15 minutes

Sufficient torque will be provided to operate against system torque at 90 percent nominal voltage for ac motors and at 84 percent nominal voltage for dc motors.

Motors will be totally enclosed unless specified otherwise.

Motors for service in hazardous areas will be individually considered for type of enclosure, depending on the classification, group, and division of the hazardous area in question.

E.3.1.6.2 Bearings. Double-shielded, grease-prelubricated, antifriction bearings will be furnished where commercially available. Motor leads will be terminated in the limit switch compartment.

E.3.1.6.3 Space Heaters. Motor operators will have 240 V rated space heaters energized at 120 VAC. Space heater leads will be terminated in the limit switch compartment.

E.3.2 Power and Control Wiring

E.3.2.1 Design Conditions

In general, conductors will be insulated on the basis of a normal maximum conductor temperature of 90° C in 40° C ambient air, with a maximum emergency overload temperature of 130° C and a short-circuit temperature of 250° C. In areas with higher ambient temperatures, larger conductors will be used or higher temperature rated insulation will be selected. Conductor size and ampacity will be coordinated with circuit protective devices. Cable feeders from 4.16 kV switchgear to power equipment will be sized so that a short-circuit fault at the terminals of the load will not result in damage to the cable before normal operation of fault interrupting device (breaker is tripped or fuse is melted).

Instrument cable will be shielded and twisted to minimize electrical noise interference as follows:

- Aluminum-polyester tape with 100 percent coverage and copper drain wire will be used for shielding.
- Low-level analog signal cables will be made up of twisted and shielded pairs.
- Except where specific reasons dictate otherwise, cable shields will be electrically continuous. When two lengths of shielded cable are connected together at a terminal block, a point on the terminal block will be used for connecting the shields.
- For multi-pair cables using individual pair shields, the shields will be isolated from each other.

To be effective, instrument cable shields will be grounded on one end as follows:

- The shields on grounded, as well as ungrounded, thermocouple circuits will be grounded at the thermocouple well.

- Multi-pair cables used with thermocouples will have individually isolated shields so that each shield will be maintained at the particular couple ground potential.

- Each resistance temperature detector (RTD) system will be a three-wire system consisting of one power supply and one or more RTDs and will be grounded at only one point.

- RTDs embedded in windings of transformers and rotating machines will be grounded at the frame of the respective equipment.

- The low or negative potential side of an instrument signal pair will be grounded at the same point where the shield is grounded. Where a common power supply is used, the low side of each signal pair and its shield will typically be grounded at the power supply.

E.3.2.2 Conductors

E.3.2.2.1 Design Basis. Electrical conductors will be selected with an insulation level applicable to the system voltage for which they are used and ampacities suitable for the load being served. The type of cable used will be determined by individual circuit requirements and individual equipment manufacturer's recommendations.

E.3.2.2.2 Cable Ampacities. The maximum ampacities for any cable will be in accordance with the NEC. In addition to ampacity, special requirements such as voltage drop, fault current availability, and environment will be taken into consideration when sizing cable.

E.3.2.3 Insulation

Cable insulation and construction will be as follows.

E.3.2.3.1 Flame Retardance. To minimize the damage that can be caused by a cable fire, cables will have insulations and jackets with nonpropagating and self-extinguishing characteristics. As a minimum, these cables will meet the flame test requirements of IEEE 383, using a gas-burner flame source. These characteristics are essential for cables installed in electrical cable tray in the plant.

E.3.2.3.2 Medium Voltage Power Cable. Power cable with minimum 5 kV class insulation will supply all 4.16 kV service and will be routed in trays, conduits, or underground duct banks.

E.3.2.3.3 Low Voltage Power Cable, 600 Volts. Power cable with 600 V class insulation will supply power to loads at voltage levels of 480 VAC and below and 125 VDC and below. Cables will be routed in trays, conduits, or ducts.

E.3.2.3.4 Control Cable, 600 Volts. Nonshielded control cable with 600 V class insulation will be used for control, metering, and relaying. Cables will be routed in trays, conduits, or ducts.

E.3.2.3.5 Instrument Cable, 300 or 600 Volts. Instrument cable will be used for control and instrument circuits that require shielding to avoid induced currents and voltages.

E.3.2.3.6 Thermocouple Extension Cable. Thermocouple extension cable will be used for extension leads from thermocouples to junction boxes and to instruments for temperature measurements. Cables will be routed in trays or conduits.

E.3.2.3.7 High Temperature Cable. High temperature cable will be used for wiring to devices located in areas with ambient temperatures normally above 75° C. Cables will be routed in conduit. Cable lengths will be minimized by terminating the cable at terminal boxes or conduit outlet fittings located outside the high temperature area and continuing the circuit with control or thermocouple extension cable.

E.3.2.3.8 Lighting and Fixture Cable. Lighting and fixture cable designations and conductor sizes will be identified on the drawings. The wire used for interior lighting and receptacles will be copper 600 V, 75-degree type THWN insulation or equal.

E.3.2.3.9 Grounding Cable. Grounding cable will be insulated or uninsulated bare copper conductor sized as required.

E.3.2.3.10 Switchboard and Panel Cable. Switchboard and panel cable will be insulated to 600 V. Cable will be NEC Type SIS or XHHW-2, meeting the UL VW-1 flame test.

E.3.2.3.11 Special Cable. Special cable will include cable supplied with equipment, prefabricated cable, coaxial cable, communication cable, etc. This cable will normally be supplied by a particular manufacturer. Special cable will be routed in accordance with the manufacturer's recommendations.

E.3.2.3.12 Miscellaneous Cable. If other types and constructions of cable are required as design and construction of the unit progress, they will be designated and routed as required.

E.3.2.4 Testing Requirements

Preoperational tests will be performed on insulated conductors after installation, as follows:

- Insulated conductors with insulation rated 5,000 V and above will be given a field dc insulation test as specified in Part 6 of ICEA Standards S-68-516 and S-66-524.
- Low-voltage cables will be either insulation-resistance tested before connecting to equipment or functionally tested (at equipment operation voltage) as part of the checkout of the equipment system.
- Insulated conductors will be continuity-tested for correct conductor identification.

E.3.2.5 Installation

Cable installation will be in accordance with the following general rules:

- Cables will be routed as indicated in the circuit raceway schedule
- Cable pulling tension will not exceed the maximum tension recommended by the cable manufacturer, and the pulling tension in pounds at a bend will not exceed the cable manufacturer's recommendations for sidewall pressure. Minimum bend radii will not exceed the manufacturer's recommendations.
- Cable will be exercised to prevent tension and bending conditions in violation of the manufacturer's recommendations.
- Cable supports and securing devices will have bearing surfaces located parallel to the surfaces of the cable sheath and will be installed to provide adequate support without cutting or deforming the cable jackets or insulation.

- Nylon ties will be used to lace together conductors entering panelboards, control panels, and similar locations after the conductors have emerged from their supporting raceway and before they are attached to terminals.

- Both ends of circuits will be identified.

- Spare conductors of a multiconductor cable will be left at their maximum length for possible replacement of any other conductor in the cable.

- Cables will be installed in accordance with manufacturer's requirements and recommendations.

E.3.2.6 Connectors

This subsection defines methods of connecting cable between electrical systems and equipment. In this subsection, the term "connector" is applied to devices that join two or more conductors or are used to terminate conductors at equipment terminals to provide a continuous electrical path.

Connector material will be compatible with the conductor material to avoid the occurrence of electrolytic action between metals. Connectors will meet the bolt hole requirements of Paragraph CC1-4.05 of NEMA Standard Publication for Electric Power Connectors, Publication CC1.

Medium voltage cables will have stress cones at their terminations. Stress cones will be the preformed type suitable for the cable to which they are to be applied.

Power cables will not be spliced. Control and low-level instrument cable will be spliced only at pigtails and at the transition to high temperature wire. Connections will be made in condulet fittings or junction boxes, using terminal blocks or an appropriate connector.

E.3.3 Protective Relaying

The selection and application of protective relays are discussed in the following paragraphs. These relays protect equipment in the electrical transmission, generation, and distribution systems.

E.3.3.1 General Requirements

The following general requirements apply to all protective relay applications:

- The protective relaying scheme will be designed to remove or alarm any of the following abnormal occurrences:
  - Overcurrent
  - Undervoltage or overvoltage
  - Frequency variations
  - Overtemperature
  - Abnormal pressure
  - Open circuits and unbalanced current
  - Abnormal direction of power flow

- The protective relaying system will be a coordinated application of individual relays. For each monitored abnormal condition, there will exist a designated primary device to detect that condition. If possible, failure of any primary relay will result in the action of a secondary, overlapping scheme to detect the effect of the same abnormal occurrence. The secondary relay may be the primary relay for a different abnormal condition. Alternate relays may exist to detect the initial abnormal condition but with an inherent time delay so that the alternate relays will operate after the primary and secondary relays. Similarly to secondary relays, the alternate relays may be primary relays for other abnormal conditions. Protective relays will be selected to coordinate with protective devices supplied by manufacturers of major items and the thermal limits of electrical equipment, such as transformers and motors.

- Secondary current produced by current transformers will be in the 0-5 A range, and voltage signals produced by voltage transformers will normally be 120 V.

E.3.3.2 Generator Protective Relays

Protective relay packages will be provided to minimize the effects of the following faults and malfunctions:

- Generator phase faults
- Generator stator ground faults
- Stator open circuits and unbalanced currents (negative sequence)
- Loss of excitation
- Backup protection for external system faults

- Reverse power
- Generator voltage transformer circuit monitoring
- Underfrequency/overfrequency
- Breaker failure

Equipment furnished with the generator's excitation equipment will provide the following additional protection:

- Underexcitation
- Overexcitation
- Generator field ground faults
- Excessive volts per hertz

Additional generator protective monitoring equipment will be provided to protect against the following:

- High bearing temperatures
- Overspeed conditions
- Excessive vibrations
- Generator overheating
- Loss of generator coolant
- High generator coolant temperature

A typical complement of protective relays for the turbine generator may be as follows. The actual protective relaying to be used will be similar and will be developed during design stages:

- Generator Differential Relay (Device 87-G) - This relay will provide primary generator protection against three-phase and phase-to-phase faults within the generator. This relay will not detect ground faults within its zone of protection.

- Generator Ground Relay (Device 64-G) - This will be a low voltage pickup, overvoltage relay that will sense voltage across the generator neutral grounding transformer secondary resistor when a ground fault occurs in the generator, generator phase bus duct, generator step-up transformer low voltage windings, or the surge protection and voltage transformer equipment.

- Negative Sequence Relay (Device 46) - This relay will protect against unbalanced phase currents resulting from unbalanced loading, unbalanced faults, a turn-to-turn winding fault, or an open circuit. Negative sequence currents exceeding the generator allowable limits will result in overheating of the generator rotor.

- Loss-of-Field Relay (Device 40) - This relay, complete with timer, will protect against thermal damage caused by underexcitation and loss of field. This relay will provide back-up protection for excitation system protective devices furnished with the generator.

- Reverse Power Relay (Device 32) - This relay will protect the turbine generator by detecting generator reverse power flow or motoring. This relay will initiate a normal sequential shutdown.

- Voltage Balance Relay (Device 60) - This relay will monitor two voltage transformer circuits to the generator voltage regulator and protective relays. Upon loss of relaying potential, this relay will disable the loss-of-field relay to avoid false tripping of the unit. Upon loss of potential to the voltage regulator, the voltage balance relay will transfer the voltage regulator from the automatic to manual mode of operation. An alarm will be actuated upon loss of either potential.

- Underfrequency Relay (Device 81) - This relay will detect underfrequency conditions.

- Overvoltage Relay (Device 27) and Undervoltage Relay (Device 59) - The voltage regulators and excitation system will include interlocks and protective circuits to prevent operating the generator beyond its design limits. These relays will alarm if the voltage regulator fails to maintain voltage within design limits.

- Field Ground Fault Protection Relay (Device 64F) - This relay will alarm grounds on the generator field.

- Generator Backup Distance Relay (Device 21G) - This relay will provide backup protection against external system faults. This relay will operate only if an external system fault persists after all other primary system relays, including breaker failure, have failed to operate. This relay will trip the generator lockout relay.

E.3.3.3 Power Transformer Relays

E.3.3.3.1 Generator Transformer. The generator step-up transformer will be protected against the effects of the following conditions:

- Phase faults
- Ground faults
- Sudden pressure

This protection will be provided by the following relays:

- Differential Relay (Device 87-T) - This relay will provide transformer primary protection by detecting three-phase and phase-to-phase faults in the generator transformer low voltage delta-connected windings and three-phase, phase-to-phase, and phase-to-ground faults in the generator transformer high voltage wye-connected windings.

- Time Overcurrent Relay (Device 51-TN) - This relay will provide sensitive backup protection for ground faults in the external system.

- Sudden-Pressure Relay (Device 63-T) - This relay will detect a rapid increase in pressure within the transformer tank associated with an internal fault. This relay will be furnished with the transformer.

Loss of cooling and resulting high temperature will be alarmed.

E.3.3.3.2 **<u>Unit Auxiliary Transformers</u>.** The unit auxiliary transformers will be protected against the effects of the following conditions:

- Phase faults
- Ground faults
- Sudden pressure

This protection will be provided by the following relays:

- Differential Relay (Device 87ST) - This relay will provide primary protection for the high voltage and low voltage windings of the unit auxiliary transformers and for the cable connecting each low voltage winding to each incoming main breaker in the plant metal-clad switchgear lineups. This relay offers protection against phase-to-phase and three-phase faults. Device 87ST is relatively insensitive to ground faults on the secondary side of the transformer should the fault current magnitudes be less than the maximum available ground fault current.

- Time Overcurrent Relay (Device 51N) - This relay will be connected to the bushing current transformer on the neutral of the low voltage winding of the unit auxiliary transformer. This relay will also provide backup protection for ground faults in the transformer low voltage winding, in the cable, on the switchgear buses, or on feeders emanating from the switchgear lineups.

- Sudden-Pressure Relay (Device 63) - This relay will detect a rapid increase in pressure within the transformer tank associated with an internal fault. This relay will be furnished with the transformer.

E.3.3.4 Metal-Clad Switchgear

The protective relays used in the 4,160 V metal-clad switchgear lineups are discussed in the following paragraphs.

E.3.3.4.1 Incoming Breakers. Each incoming breaker will have time overcurrent relays (Device 51) and a time overcurrent ground detection relay (Device 51N). Device 51 will detect and trip the respective switchgear incoming breaker for sustained overloads and short-circuit currents on the switchgear bus. These relays will provide backup protection for faults on feeders emanating from the switchgear lineups. Device 51N will be residually connected to switchgear current transformers and provide primary protection for ground faults on the switchgear bus and backup protection for ground faults in feeders emanating from the switchgear lineup.

The medium voltage switchgear bus will have undervoltage relays (Device 27) or transducers to detect bus voltage drops to a preset level.

E.3.3.4.2Low Voltage Load Center. Each load center transformer will be protected by a 4.16 kV circuit breaker. Protection devices will include time overcurrent relays (Device 51), instantaneous current relays (Device 50), and ground fault relays (Device 51N), or a multifunction transformer protection relay.

E.3.3.4.3Medium Voltage Motor Feeders. Each single-speed induction motor will be protected by main line fuses and a microprocessor motor protection/management relay (MPR). The MPR will provide primary equipment and cable time overcurrent, instantaneous overcurrent, open phase, and zero sequence protection.

E.3.3.5 480 Volt Load Center Switchgear The MCCs will be powered directly from the secondary of the load center transformer through a main secondary circuit breaker.Each magnetic starter within an MCC that supplies power to a motor will have an adjustable motor circuit protector and a thermal overload element in the starter.

E.3.3.5.1 **<u>480 Volt Motor Control Centers</u>.** MCCs will be protected by the 480 V switchgear feeder breakers, which have adjustable long-time and short-time SSTD elements for phase protection and ground fault protection in a manner similar to that described in Subsection E.3.3.5, 480 Volt Load Center Switchgear. The SSTD will protect the MCC feeder circuit and the bus against sustained short-circuit currents and serve as backup protection for MCC feeder circuits.

Each magnetic starter within an MCC that supplies power to a motor will have an adjustable motor circuit protector and a thermal overload element in the starter.

Certain nonmotor loads will be fed from MCC feeder circuit breakers. The feeder breakers will be thermal-magnetic molded-case breakers sized to protect supply cable and individual loads.

E.3.3.5.2 **<u>480 Volt Power Panels</u>.** Power panels will have thermal-magnetic circuit breakers sized to protect supply cable and individual loads.

E.3.4 Classification of Hazardous Area

Areas where flammable and combustible liquids, gases, and dusts are handled and stored will be classified for the purpose of determining the minimum criteria for design and installation of electrical equipment to minimize the possibility of ignition. The criteria for determining the appropriate classification are specified in NEC Article 500 (NFPA 70/ANSI C1).

In addition to defining hazardous areas by class and division, each hazardous element is also assigned a group classification (A, B, C, etc.). The group classifications of hazardous elements are specified in NEC Article 500 and NFPA Standard 497M.

Electrical equipment in areas classified as hazardous will be constructed and installed in accordance with NEC Articles 501 and 502.

References for use in classification of areas, as well as specification of requirements for electrical installation in such areas, include:

- NESC, ANSI C2
- NEC, ANSI C1, NFPA 70/ANSI C1
- NFC, NFPA

E.3.5 Grounding

The station grounding system will be in an interconnected network of bare copper conductor and copper-clad ground rods. The system will protect plant personnel and equipment from the hazards that can occur during power system faults and lightning strikes.

E.3.5.1 Design Basis

The station grounding grid will be designed for adequate capacity to dissipate energy from ground fault current under the most severe conditions, with grid spacing such that safe voltage gradients are maintained. The system will be in accordance with IEEE 80, IEEE 142, and NEC, NFPA 70.

Bare conductors installed below grade will be spaced in a grid pattern to be indicated on the construction drawings. Each junction of the grid below grade will be bonded together.

Ground stingers will be brought through the ground floor and connected to the building steel and selected equipment. Also, the grounding system will be extended, by way of stingers and conductor installed in cable tray, to the remaining plant equipment.

Equipment grounds will conform to the following general guidelines:

- Grounds will conform to NEC.

- Major equipment, such as switchgear, MCCs, relay panels, and control panels, will have integral ground buses that will be connected to the station ground grid.

- Electronic panels and equipment, where required, will be grounded using an insulated ground wire connected in accordance with the manufacturer's recommendations.

- Motor supply circuits to 460 V motors, which use four-conductor cable or three-conductor cable with a ground in the interstices, will use this ground for the motor ground. For 460 V motor supply circuits, which use three single-conductor cables, a separate ground conductor will be used.

- All 4,000 V motors will have a minimum of one 1/0 AWG bare copper ground conductor connected between the motor frame and the station ground grid.
- Single-conductor ground wires installed in conduit will be insulated.

E.3.5.2 Materials

Grounding materials will be as follows:

- Ground rods will be copper. Rod length and diameter will be determined by soil resistivity and subsurface mechanical properties. Where the required ground rod length exceeds 10 feet, standard sections will be connected together.
- Cable will be either soft-drawn copper with Class B stranding or copper-clad steel.
- Compression-type connectors that meet the requirements of IEEE 837 will be used for the buried connectors.
- Clamps, connectors, and other hardware used with the grounding system will be designed for that use and purchased from an approved supplier.
- Ground wires installed in conduit will be soft-drawn copper with Class B stranding and green-colored 600 V insulation. Ground wires larger than No. 6 AWG may be marked green in lieu of green-colored insulation.

E.3.6 Site Lighting

The site lighting system will provide personnel with illumination to perform general yard task, safety, and plant security. Power used to supply outdoor roadway and area lighting fixtures will be at 277 V.

E.3.6.1 Light Sources

The lighting system will be designed to provide illumination levels recommended by the following standards and organizations:

- IES RP-7 - Standard Practice for Industrial Lighting
- IES RP-8 - Standard Practice for Roadway Lighting
- IES RP-24 - Standard Practice for Lighting Offices Containing Computer Display Terminals

Light source size and fixture selections will be based on the applicability of the luminaries for the area under consideration during detail design.

E.3.6.2 Roadway and Area

Roadway and area lighting will be designed using high-pressure sodium light sources. The light fixtures will be the cutoff type designed to control and direct light within the property line of the facilities. Roadway light fixtures will be installed on hot-dip galvanized steel poles. Local task lighting will be installed on buildings or equipment.

E.3.6.3 Lighting Control

Electric power to outdoor light fixtures will be switched on and off with photoelectric controllers. Local task lighting will be controlled with photoelectric controllers and manual switches at the task.

E.3.7 Freeze Protection

A freeze protection system will be provided for outdoor equipment, as required.

Three-wire, self-regulating heating cable will be directly applied to pipe. These heating cable circuits can be assembled and installed in the field using the appropriate connection kits. Heating cable will withstand the maximum surface temperature of the pipe to which it is applied. Power distribution panelboards will furnish power to the freeze protection circuits. Power to the freeze protection circuits will be controlled by ambient thermostats; loss of power or broken cable will be alarmed.

E.3.8 Lightning Protection

Lightning protection will be provided, as required, for all structures.

Lightning protection will be provided for buildings and structures generally in accordance with NFPA 780 but will not be UL "Master" labeled.

E.3.9 Raceway and Conduit

The design and specifications for the raceway and conduit systems used to support and protect electrical cable will be in accordance with NEC provisions.

E.3.9.1 Cable Tray

Cable trays will be the trough or ladder type with a maximum rung spacing of 9 in., nominal depths of 4 to 6 in., and various widths as required. Horizontal trays will have a maximum spacing of 20 ft between cable tray supports; vertical trays, 8 ft.

Fittings (elbows, tees, etc.) will be supported in accordance with NEMA standards and will have a radius equal to or greater than the minimum bending radius of the cables they contain.

Electric systems such as special noise sensitive circuits and analog instrumentation circuits will have solid bottom trays.

For 4.16 kV power cables, the summation of the cross-sectional areas of cable in tray will be limited to 30 percent of the usable cross section of the tray. For 480 V power and control cables, the limit will be 40 percent. For instrument cable, the limit will be 50 percent.

The minimum design vertical spacing for trays will be 12 in., measured from the bottom of the upper tray to the top of the lower tray. At least a 9-in. clearance will be maintained between the top of a tray and beams, piping, or other obstacles to facilitate installation of cables in the tray. A working space of not less than 24 in. will be maintained on at least one side of each tray.

Vertical trays will have covers that allow ventilation. Solid bottom tray and outdoor tray will have solid covers. The top tray of horizontal tray runs located under floor grating will also have solid covers. All outside cable tray will be covered.

E.3.9.2 Conduit

Conduit will be used to protect conductors routed to individual devices, in hazardous areas, and where the quantity of cable does not economically justify the use of cable tray.

Electrical metallic tubing (EMT) will be used indoors in nonhazardous areas for lighting branch circuits and communication circuits.

PVC, EMT, and rigid galvanized steel conduit will be used for underground duct banks and some below grade, concrete-encased conduit.

Liquidtight, flexible metallic conduit will be used for connections to accessory devices such as solenoid valves, limit switches, pressure switches, etc.; for connections to motors or other vibrating equipment; and across areas where expansion or movement of the conduit is required.

Exposed conduit, unless specific environmental requirements dictate the use of plastic or aluminum conduit, will be rigid galvanized steel.

Exposed conduit will be routed parallel or perpendicular to dominant surfaces.

Conduit in finished areas, such as the offices and control room, will normally be concealed. Conduit will be routed at least 6 in. from the insulated surfaces of hot water, steam pipes, and other hot surfaces. Where conduit must be routed parallel to hot surfaces, high-temperature cable will be used.

Conduit will be sized in accordance with NEC requirements. Conduit will be securely supported within 3 ft of connections to boxes and cabinet.

E.3.9.3 <u>Duct Bank and Manholes</u>

Underground circuits will be installed in reinforced duct bank, unreinforced duct bank, or in direct buried conduit, as required by the final design.

Underground conduits will be rigid Schedule 40 PVC. Stub-ups will be made using rigid galvanized steel conduit elbows and galvanized fittings as required.

Conduit runs installed below grade (except in floor slabs) will be encased in a minimum of 3 in. of concrete on all sides. The minimum spacing between conduits in underground duct banks will be 1-1/2 in. Reinforced concrete will be used in heavy traffic areas.

The top of concrete encasement for underground conduit will be a minimum of 24 in. below grade. Horizontal bends in underground conduits will be made using long radius sweeps.

Duct banks will slope downward toward manholes at a slope of 3 in. per 100 ft, minimum.

In paved areas, conduits will be stubbed up in a coupling flush with finished grade. In unpaved areas, conduits will be stubbed up in a coupling 6 in. above finished grade and will be encased.

As a minimum, 20 percent (or not less than one) spare conduits (2 in. minimum size) will be installed in underground duct banks, except for single- or double-conduit duct banks for street lighting or to individual remotely located equipment.

In paved areas, spare conduits will be stubbed up in a coupling (with conduit plug) flush with finished grade. In unpaved areas, spare conduits will be stubbed up in a coupling (with conduit plug) 6 in. above finished grade and will be encased.

Reinforced concrete manholes and electrical vaults will be provided, where required, so that cable may be installed without exceeding allowable pulling tensions and cable sidewall pressures. Each manhole will have the following provisions:

- Provisions for attaching cable pulling devices
- Provisions for racking cables
- Manhole covers of sufficient size to loop-feed the largest diameter cable through the manhole without splicing

Conduit from manholes to the equipment at remote locations will be changed to rigid steel before emerging from below grade.

Duct bank and manholes will be designed in accordance with the seismic criteria defined in the Structural Design Criteria.

E.3.10 Cathodic Protection System

Buried carbon steel structures will be provided with cathodic protection because of the potential hazard should a leak develop. If the site's soil resistivity is less than 200 ohmmeter, then cathodic protection will be provided for all other buried structures. The cathodic protection system for steel structures will be either impressed current or sacrificial galvanic anode, depending on soil conditions and pipe size.